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HABITUATION OF THE ORIENTING REFLEX IN BRAIN DAMAGED PATIENTS

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ABSTRACT

Habituation and dishabituation of the heart rate, skin conductance, and alpha blocking components of the orienting reflex to an auditory stimulus were examined for brain-damaged and non-brain-damaged *S*s. The non-brain-damaged group displayed the expected habituation for all of these response variables but the brain-damaged group displayed evidence of habituation only for the skin conductance measure. The brain-damaged group also displayed higher initial skin conductance response amplitudes and smaller initial alpha blocking responses to the auditory stimulus than did the non-brain-damaged group. The results are discussed in terms of their implications for mechanisms of habituation and for other psychological deficits in brain-damaged patients.

DESCRIPTORS: Cortical brain damage, Habituation, Orienting reflex, Autonomic nervous system. (F. A. Holloway)

The purpose of this study was to compare the habituation of certain electrodermal, cardiovascular, and electroencephalographic (EEG) components of the orienting reflex (OR) in brain-damaged (BD) and non-brain-damaged (NBD) patients. This work is part of a systematic investigation of psychophysiological responsivity in BD patients and of the relationship between such responsivity and performance (Parsons & Chandler, 1969; Holloway & Parsons, 1969).

In earlier studies on groups of BD patients who had sustained at least some degree of cortical impairment, tonic levels of electrodermal activity were found to be generally higher in these *S*s than in hospitalized controls (Parsons & Chandler, 1969), and unilaterally lesioned patients had higher levels of electrodermal activity on the side of the body contralateral to the lesion than on the ipsilateral side (Holloway & Parsons, 1969). The extent of this elevated electrodermal activity was greater during initial rest periods or during periods involving simple sensory stimulation than during periods requiring motor responses and/or cognitive involvement of the *S*. These data were discussed in terms of a failure

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of cortical modulation of lower brain centers governing autonomic activity which permitted the increased electrodermal activity during "passive" sensory stimulation.

The habituation of the OR is a particularly suitable paradigm for examining the extent and character of psychophysiological responsiveness. Habituation has been shown to be a highly labile, reversible process which occurs rapidly if the stimuli are not meaningful, not intense, and expected, and which occurs more slowly or not at all under conditions such as increased alertness (Scholander, 1960), sleep (Johnson & Lubin, 1967), and central nervous system (CNS) disturbances (Davidoff & McDonald, 1964; Briullova, 1965). In our laboratory[1] slower habituation of the BD's skin resistance response (SRR) was found with repeated presentations of a 2-sec tone. To date, the only published study to examine quantitatively the habituation of the OR in BD human *S*s is that of Davidoff and McDonald (1964). While these authors found no differences between BD and NBD in the habituation of SRR or the alpha blocking response to repeated presentations of a 10-sec tone, they did find that the BD failed to habituate their heart rate (HR) and vasomotor responses. These authors did not attempt a systematic evaluation of the diphasic HR measure they employed, of differences in stimulus conditions which would produce dishabituation, or of changes in stimulus conditions. The authors are aware of no investigations of dishabituation in brain-damaged *S*s.

Thus, the present investigation was addressed to the following questions: (1) do BD and NBD differ in the magnitude of their HR, electrodermal, or EEG orienting responses or in their tonic levels of psychophysiological activity during the presentation of auditory stimuli, lasting 10 or 2 sec? (2) Do BD and NBD differ in the habituation rate of these phasic psychophysiological responses or in the adaptation of more tonic levels of psychophysiological activity to repeated presentations of these stimuli? (3) Do BD and NBD display the expected dishabituation of the various components of the OR with a change in stimulus conditions?

Method

Subjects

The *S*s were 19 non-brain-damaged, hospital controls (NBD) and 23 brain-damaged (BD) male, Caucasian patients at the Oklahoma City Veterans Administration Hospital, equated on age and education. One NBD and 1 BD *S* were eliminated from the sample because of faulty HR recordings. None of the *S*s in this experiment had the following diagnoses: alcoholism, drug addiction, Addisons disease, emphysema, carcinoma, endocrine disturbances, heart disease, or paraplegia. The detailed demographic, medication, and diagnostic data for these *S*s have been previously reported (Holloway & Parsons, 1969). Briefly, the NBD *S*s were obtained from orthopedic and general surgical services and

[1] Unpublished study entitled, "GSR Habituation in Brain-Damaged and Normal Patients," 1965, by O. A. Parsons and P. J. Chandler.

had no indications of neurological or psychiatric disturbances. None of the BD *S*s had any diagnosed functional psychiatric disorder. The BD *S*s were obtained from the neurological service and had sustained at least some type of cortical brain damage as described by the final diagnosis and later by a neurologist's rating. On the basis of the latter dual criteria for a *S*'s inclusion in the BD group, the BD group was found to comprise approximately equal subgroups of *S*s with primarily left hemisphere involvement, *S*s with right hemisphere involvement, and *S*s with diffuse or bilateral involvement. In each of these subgroups, there were patients with varying degrees of frontal, temporal and/or parietal lobe damage which had resulted from trauma, tumors, or cerebral vascular accidents. All *S*s were capable of attending to and following instructions in the experinent.

Apparatus

All physiological measures were recorded on an 8-channel Beckman Type R Dynograph. Exosomatic electrodermal activity was measured directly in skin conductance units with a constant voltage circuit. The electrodes and bilateral electrode placements have been previously described (Holloway & Parsons, 1969). Heart rate was recorded with a Beckman Type 9857 cardiotach coupler. Standard Grass E5S electrodes were attached in a center position slightly below the rib cage on each side. Respiration was measured with a strain-gauge device fitted around the *S*'s torso at the level of the diaphragm. The signal from this device went through an RC network (a load and series capacitor) to produce a long time constant; the output was fed into a Beckman DC amplifier and written out.

The EEG system consisted of an active bandpass filter (White Instruments, No. 2925) with a center frequency of 10 Hz which selectively admitted frequencies in the alpha range (8–12 Hz) while attenuating all other frequencies. The read-out of this filter yielded 10 waves per sec with amplitude related to amount of alpha activity. Baseline percentage of EEG alpha was determined by counting the number of filtered waves exceeding the equivalent of 20 μv for 10 sec prior to each trial. Alpha Blocking was determined by summating the amplitudes of each of the 20 filtered waves for 2 sec prior to and 2 sec after stimulus onset; the Alpha Blocking index consisted of the prestimulus alpha amplitude minus the poststimulus amplitude divided by the prestimulus amplitude, i.e., percentage change in amount of EEG alpha. This system of scoring Alpha Blocking was employed because it was more sensitive to changes in alpha amplitude than the more conventional 50% reduction criterion used by many investigators. EEG (placements described in the 10–20 system) was recorded from the frontal (Fpl) to vertex (C_Z) and from the occipital (O_1) to vertex (C_Z) regions of the scalp with bipolar Grass EEG electrodes. For both anterior and posterior placements there were filtered and non-filtered channels during the Rest conditions; during the Habituation phase of the experiment only the posterior EEG was recorded.

A ground electrode, coated with Beckman EKG paste, was attached to the right forearm with a rubber arm band.

Experimental Conditions

The *S*s reclined in a comfortable arm chair in an air-conditioned, sound-attenuated room. After electrodes were attached, the lights were turned out and a low-level "white noise" was present throughout the entire session. All recording and stimulus control equipment were located in an adjacent room. The auditory stimulus was an 80 db door-type buzzer situated directly in front of the *S* in a metal panel. The stimulus presentation and control system consisted of two Hunter Timers which could be started and stopped manually.

The experimental conditions were the second two phases of an experiment reported earlier (Holloway & Parsons, 1969): (1) a series of 10 habituation trials, using a 2-sec buzzer (H-2); and (2) a series of 10 habituation trials using a 10-sec buzzer (H-10). The order of presentation for the H-2 and H-10 treatment conditions was counter-balanced across *S*s within each group. Only the first stimulus series, with either the 2- or 10-sec stimulus duration, was used in the habituation analysis. The initial trial block (trials 1–3) of the second stimulus series (with durations of either 2 or 10 sec) provided the test for dishabituation. The intertrial interval between the offset and onset of a buzzer varied from 30 to 40 sec with a mean of 35 sec. The *S* was instructed to keep his eyes closed at all times and to limit his movements. The *S* was also told that a buzzer, lasting a few seconds, would come on occasionally; he was not told that the duration of the buzzer would change.

Data Treatment

During habituation, the following measures were recorded and scored: (1) right palmar and left palmar skin conductance levels (RP-SCL and LP-SCL); (2) RP and LP skin conductance response amplitude (RP-SCR and LP-SCR), taken from the first response 0.5 to 4.0 sec after stimulus onset; (3) baseline heart rate (BL-HR) at the time of stimulus onset; (4) the highest HR, 2 to 6 beats after stimulus onset (H-HR); (5) the lowest HR, 7 to 20 beats after stimulus onset (L-HR); (6) H-HR minus L-HR change scores (H − L HR) (after Lang & Hnatiow, 1962); (7) BL-HR minus L-HR scores (BL − L HR); (8) H-HR minus BL-HR (H − BL HR); (9) mean baseline respiration rate during the 10 sec prior to stimulus onset (BL-Resp.); (10) percent EEG alpha 10 sec prior to stimulus onset (% alpha); and (11) percent of EEG alpha blocking (Alpha Blocking). Since there were no differences between LP-SCR and RP-SCR or between LP-SCL and RP-SCL, the left side recordings were arbitrarily selected for presentation. The two HR response measures, H − BL HR and BL − L HR, provided a means of assessing the contribution of acceleration and deceleration respectively to the H − L HR orienting response score, used by Davidoff and McDonald (1964). The primary statistical treatment was a three-way analysis of variance (Group × Stimulus duration with replications across Trial Blocks) performed on each response and level measure. Since conservative degrees of freedom (after Greenhouse & Geisser, 1959) were employed for all main and simple effects confounded by replication, the degrees of freedom for all F-tests were 1 and 36.

TABLE 1

Overall means (S.E.'s) of psychophysiological response measures

Groups and Stimuli	H − L HR (bpm)	BL − L HR (bpm)	H − BL HR (bpm)	LP SCR Ampl. (μmhos)	Alpha Blocking (% Change)
Non-Brain-Damaged Group					
2 Sec Stimulus	5.9 (0.5)	2.9 (0.4)	2.8 (0.4)	5.07 (1.40)	4.0 (12.6)
10 Sec Stimulus	5.3 (0.7)	3.1 (0.6)	1.6 (0.3)	1.77 (0.50)	8.0 (12.3)
Brain-Damaged Group					
2 Sec Stimulus	9.1 (1.2)	3.9 (0.4)	5.1 (1.2)	8.10 (1.90)	−8.0 (12.6)
10 Sec Stimulus	4.5 (0.4)	3.0 (0.4)	1.5 (0.3)	4.50 (0.70)	−12.0 (12.3)

Results

Tonic and Phasic Levels of Psychophysiological Activity

The first issue addressed in this study was that of possible differential orienting response magnitudes and basal psychophysiological activity in the BD and NBD groups during presentations of the auditory stimuli, lasting 2 or 10 sec. Analysis of the baseline levels of HR, SCL, percent alpha, and respiration rate showed that there were no significant overall differences in basal activity between groups or between the stimulus duration conditions for either group. There were also no significant group differences for any of the overall response magnitude measures. The overall means and standard errors for the five psychophysiological response measures (H − L HR, BL − L HR, H − BL HR, LP-SCR, and Alpha Blocking) during the 2- and the 10-sec stimulus conditions are presented in Table 1. As can be seen in Table 1, all response measures, except for the Alpha Blocking and BL − L HR measures in the NBD group, tended to be larger during the 2- than during the 10-sec stimulus condition. This latter stimulus duration effect, however, yielded significant main effects only for the H − L HR and H − BL HR measures ($F = 4.87$, $p < .05$, and $F = 5.38$, $p < .05$, respectively) and could be attributed primarily to the BD group where the simple effects for stimulus conditions were also significant for both of these measures ($F = 7.00$, $p < .05$, and $F = 5.38$, $p < .05$, respectively). Since little is known about the relationship between stimulus duration and the magnitude of psychophysiological responses, it is difficult to evaluate the significant differentiation of HR acceleration tendencies as reflected by the H − BL and H − L HR measures for the long and short-duration stimuli used in this experiment. It should be noted, however, that many investigators consider HR deceleration and not HR acceleration as the primary HR component of the OR (Graham & Clifton, 1966).

While no significant overall group differences in tonic or phasic levels of psychophysiological activity were found, it is possible that group differences would occur during initial stimulus presentations. In answer to this question, statistical analyses indicated that baseline measures again failed to differentiate the two groups, but that the orienting response measures did so partially. The BD group tended to display somewhat higher magnitude HR acceleration responses and somewhat lower magnitude HR deceleration responses during the first trial

block than did the NBD group, but these differences were not significant. The BD group displayed significantly higher SCR amplitudes (10.09 μmhos) than did the NBD group (6.52 μmhos) on the first trial block ($F = 5.02, p < .05$). Finally, there was a significant difference between the BD and NBD groups in the magnitude of their Alpha Blocking responses on Trial Block 1 ($F = 10.77, p < .01$) in which the NBD group displayed a mean Alpha Blocking index of 30% reduction of their alpha amplitude which was significantly different from zero ($t = 2.30, df = 17, p < .05$) while the BD group displayed a mean reduction in alpha of only 7% which was not significantly different from zero ($t = 0.38$).

In summary, the analyses of psychophysiological activity during the presentations of auditory stimuli indicate that: (1) BD and NBD groups did not differ in initial or overall baseline levels of activity; (2) there were no significant differences between the stimulus duration conditions for any measures except those reflecting the HR acceleration response; (3) while the BD and NBD groups did not differ significantly in the overall magnitudes of various components of their orienting response, the BD group did display significantly larger SCRs and significantly smaller Alpha Blocking responses during the initial trial block.

Habituation of Psychophysiological Activity

The second major question investigated in this study was that of possible group differences in habituation rate of phasic psychophysiological responses and in adaptation of tonic psychophysiological activity with repeated presentations of stimuli. Answering the latter part of the question first, analyses of changes in baseline levels of HR, SCL, percent alpha, and respiration rate revealed no significant differences across trial blocks for either group.

The habituation curves for the HR response measures are presented in Fig. 1 (with the two stimulus duration conditions collapsed). The NBD group displayed the expected monotonic decline in the magnitude of their HR deceleration response as reflected in both the H − L HR and BL − L HR measures, while the BD group did not display a similar decrease in either of these measures. The differential HR habituation in the two groups was significant as indicated by the analysis of variance procedure. For both the H − L HR and BL − L HR measures, but not the H − BL measures, significant main effects were found for Trial Block ($F = 9.19, p < .01$, and $F = 4.15, p < .05$, respectively), and for the Group × Trial Block interaction ($F = 5.57, p < .05$, and $F = 4.34, p < .05$, respectively). Significant simple effects of Trial Blocks were noted for the NBD group on the H − L HR ($F = 10.97, p < .01$) and BL − L HR ($F = 8.85, p < .01$) measures, while no significant Trial Block effects were found on either measure for the BD group.

The habituation curve for the electrodermal response is presented in Fig. 2. The analysis of variance procedure yielded a significant overall Trial Block effect ($F = 26.38, p < .01$), which reflects the monotonic decline seen in Fig. 2 and which was significant for both the NBD ($F = 19.68, p < .01$) and BD ($F = 33.26, p < .01$) groups. The habituation curve for the Alpha Blocking response is presented in Fig. 3. Although there was a significant main effect for Trial Blocks ($F = 11.00, p < .01$) as indicated by analysis of variance, this

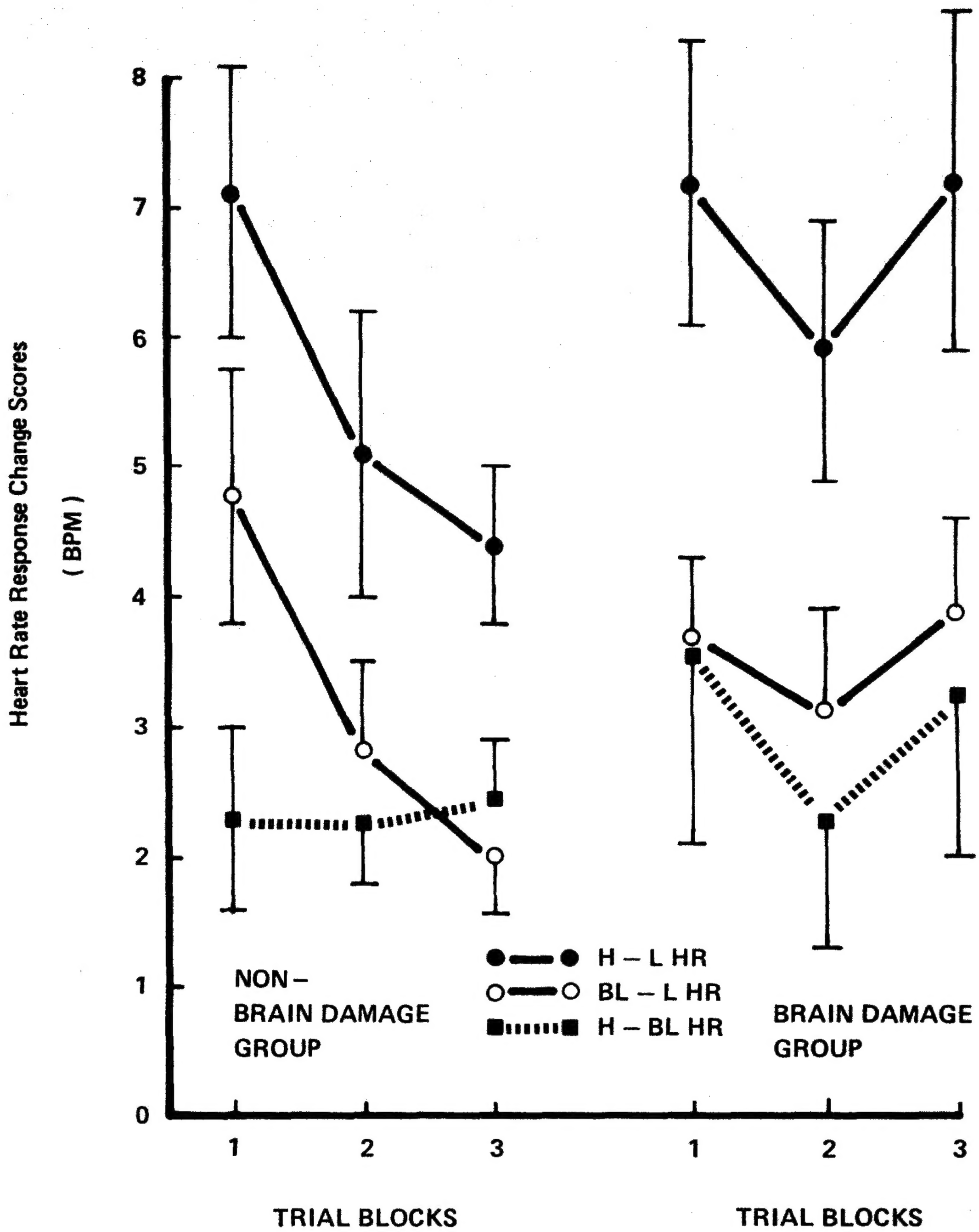

FIG. 1. Habituation curves for the HR response measures ($\bar{X}$ and S.E.)

effect was due primarily to a significant decrease across trials in the NBD group's Alpha Blocking index ($F = 8.73$, $p < .01$). The BD group did not show a significant decrease across trials.

In summary, the analysis of variance procedures indicate that the NBD group habituated their cardiac deceleration, electrodermal, and Alpha Blocking responses to the auditory stimuli while the BD group appeared to habituate only their electrodermal responses.

Dishabituation and Other Criteria of Habituation

The last question to which this study was addressed was that of differences in the dishabituation tendencies of orienting response measures in the BD and NBD groups. Dishabituation has been regarded by some investigators as a critical test for the occurrence of habituation as distinguished from other physio-

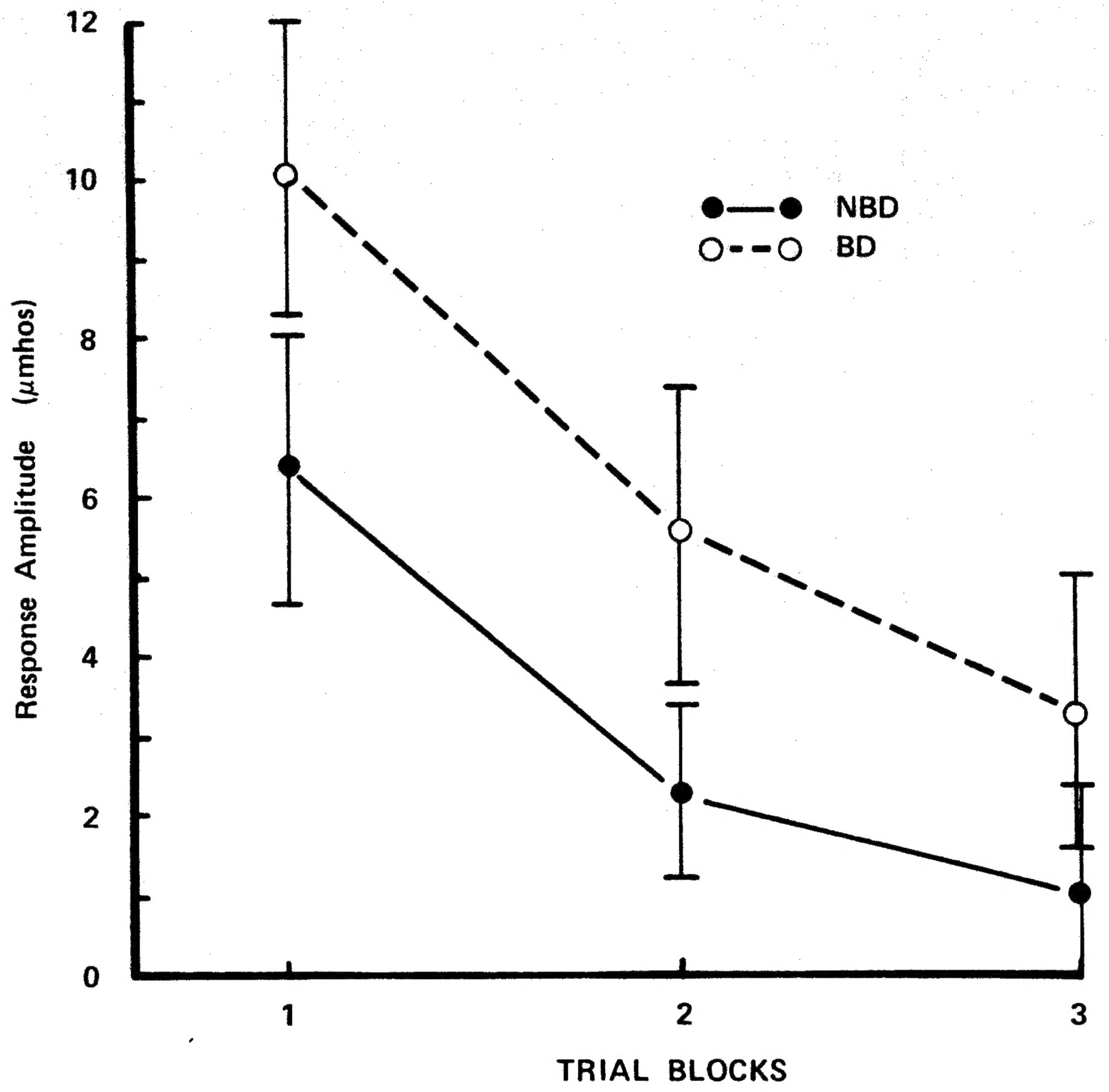

FIG. 2. Habituation curve for the electrodermal response measure ($\bar{X}$ and S.E.)

logical factors such as fatigue, etc. (Thompson & Spencer, 1966). The results of such an analysis of the change in response amplitude on the last trial block of the first stimulus series to the first trial block of the second stimulus series is found in the last column of Table 2. The NBD group displayed significant dishabituation tendencies only for the H − L HR, BL − L HR, and LP SCR response measures. Although most of the NBD *S*s displayed dishabituation of their Alpha Blocking responses, this trend was not significant. The BD group failed to manifest significant dishabituation on any of the response measures.

Davidoff and McDonald (1964) raised the question of whether their results on habituation in BD (similar to those reported in the previous section) could have been due to higher variance or more extreme scores in the BD group. Thus, Wilcoxon Matched Pairs Sign Rank Tests were performed on the early (Trial Block 1 minus Trial Block 2) and the late (Trial Block 1 minus Trial Block 3) habituation scores for each response measure. As seen in Table 2, the NBD group showed significant early and late habituation of all response measures except H − BL HR, while the BD group displayed both early and late habituation only for the electrodermal response measure. The BD group also showed a

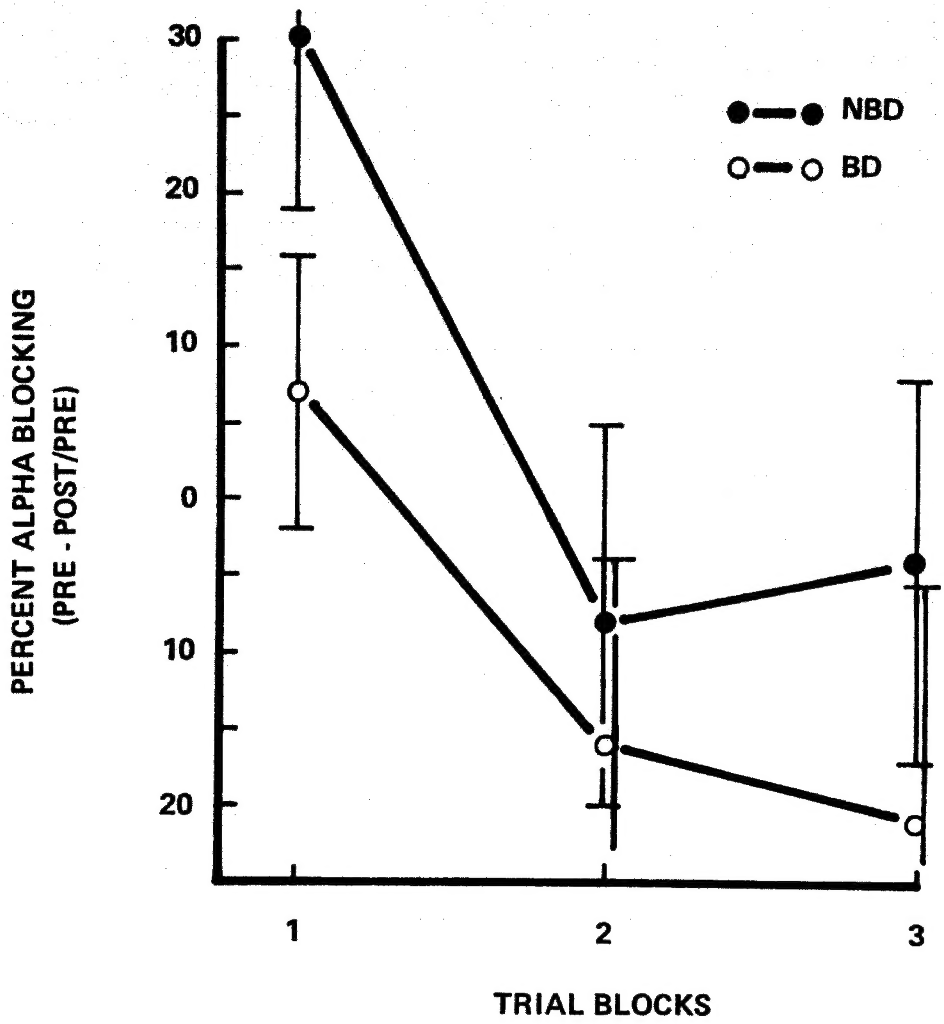

FIG. 3. Habituation curve for the Alpha Blocking response measure ($\bar{X}$ and S.E.)

significant initial decrease in H − L HR which was not evident in the later habituation scores for this measure. Since, however, there were no significant early or late habituation tendencies for the BD group on the BL − L HR measure, the initial decline on the H − L HR may well be accounted for by the initial significant decrease in the HR acceleration scores (H − BL HR).

In summary, the non-parametric analyses of habituation yielded results closely paralleling those of the parametric analysis in most respects: (1) the NBD group displayed significant habituation in their H − L HR, BL − L HR, Alpha Blocking, and LP SCR response measures but significant dishabituation was found only for the HR and electrodermal measures; (2) the BD group displayed no evidence of habituation for the HR response or alpha blocking variables, although there was a slight initial decrease in the HR acceleration response; the BD group also continued to display significant evidence of habituation of their electrodermal responding, but failed to display dishabituation of that response.

Discussion

The major findings of this investigation were highly comparable to those reported by Davidoff and McDonald (1964), namely, the BD group tended to habituate the electrodermal but not the HR component of their OR to an auditory stimulus. In neither the present study nor the study of Davidoff and

TABLE 2

Habituation and dishabituation of various components of the orienting response

Response Variables and Groups	Habituation Trends: Percentage of *S*s Decreasing[a] — Trial Block I – II	Habituation Trends: Percentage of *S*s Decreasing[a] — Trial Block I – III	Dishabituation: Percentage of *S*s Increasing[a]
H – L HR (bpm)			
NBD	89.0**	89.0**	88.0**
BD	86.0**	50.0	45.0
BL – L HR (bpm)			
NBD	89.0**	83.0**	94.0**
BD	59.0	41.0	41.0
H – BL HR (bpm)			
NBD	67.0	61.0	22.0
BD	73.0*	55.0	50.0
LP SCR Ampl.			
NBD	94.0**	94.0**	69.0*
BD	90.0**	85.0**	65.0
Alpha Blocking			
NBD	83.0**	83.0**	67.0
BD	59.0	59.0	45.0

[a] Mean response amplitude differences between trial blocks tested with Wilcoxon Matched Pairs Sign Rank Test; remaining percentage of *S*s either increased or did not change during habituation and either decreased or did not change during dishabituation.

* $p < .05$.

** $p < .01$.

McDonald were there any overall group differences in response magnitude. However, in the present study the BD group displayed higher initial response magnitudes than the NBD for electrodermal response measures and lower initial response magnitudes than the NBD group for Alpha Blocking. The finding of higher electrodermal OR amplitudes is consistent with earlier work in which BD *S*s displayed higher electrodermal activity (Parsons & Chandler, 1969).

Although it was impossible to specify the exact location and extent of neural damage to cortical systems in the present study, the electrodermal findings are consistent with both the earlier work of Wang and Brown (1956) and the more recent studies of Wilcott (1969) which demonstrated inhibitory control by anterior or sensorimotor cortices over electrodermal activity. The finding of significantly lower Alpha Blocking response magnitudes in the BD group, while not supporting the results of the Davidoff and McDonald study, is consistent with the findings of two earlier investigations (Blum, 1957; Wells, 1962). The failure of the BD group to show Alpha Blocking cannot be attributed to a lower percentage of baseline alpha activity since the NBD and BD groups did not differ on this measure.

Davidoff and McDonald (1964) had suggested that the failure of their BD population to show habituation of the HR component of the OR may have been

due to higher variance or extreme scores in that group. Such an explanation for the present study is not very likely. Three estimates of habituation (analysis of variance of response amplitudes, non-parametric analysis of early and late decreases in response amplitude, and non-parametric analysis of dishabituation) indicated that the NBD significantly decreased the magnitude of their HR deceleration response across trials while the BD group did not. The apparently significant initial decline in the BD group's H − L HR measure was due to a slight but significant decrease in this group's HR acceleration score and not their HR deceleration response decreases. This latter finding suggests that the H − L HR score devised by Lang and Hnatiow (1962) may not be the best estimate of the HR OR in all situations. The fact that there were no significant differences in basal autonomic activity or in percent alpha would seem to rule out the explanation that the BD group's poor habituation of cardiac deceleration responses to auditory stimuli was due either to increased arousal levels *per se* or to drowsiness.

Thus, in summary the BD group displayed the following effects, all of which either indicate a malfunction in the manifestation of some components of the orienting response or a disruption in the habituation of some components of the orienting response: (1) lack of habituation in their HR deceleration response across trials; (2) absence of a significant Alpha Blocking response to auditory stimuli; and (3) failure to manifest dishabituation of their electrodermal response, even after displaying habituation of this response which was not different from that of the NBD group. While the principal results of this study parallel those of Davidoff and McDonald (1964), there is some indication of a more pervasive defect in habituation as indicated by the failure of the BD group to manifest a significant Alpha Blocking response or to dishabituate their "habituated" SCRs.

Finally, the present set of data, which demonstrates that at least one autonomic variable, SCR amplitude, does manifest habituation in the BD *S*s, while at least one other autonomic variable, the HR deceleration response, clearly does not display habituation tendencies in these *S*s, suggests several propositions concerning mechanisms of habituation: (1) the conditions were established to demonstrate that an adequate "model" of the stimulus (after Sokolov, 1960) existed for these BD *S*s, in so far as they demonstrated habituation for the electrodermal measure; (2) it cannot be argued (after Worden, 1966) that variations in the position of the auditory receptors in the BD *S*s during habituation accounts for the lack of HR habituation in that group (since another response did in fact habituate); (3) at least some portion of the inhibitory processes, capable of attenuating the autonomic efferent components of the OR during habituation, must have been operative; (4) all autonomic components of the OR do not necessarily or uniformly reflect the degree to which a stimulus has "novel" value for the *S*; (5) while the cortex may play an important role in the modulation of autonomic activity, it apparently cannot provide the necessary and sufficient neural apparatus for the habituation of all components of the OR.

Even though the present study, as well as that of Davidoff and McDonald (1964), shows that there is not a uniform disturbance of habituation processes in BD patients, the particular impairment of HR habituation in these patients

may be related to performance deficits in such *S*s. Recently the authors have found that the magnitude of psychophysiological responding to the warning signal of a simple reaction time task is inversely related to efficiency of reaction time performance (Holloway & Parsons, 1970), a result opposite to that found in control *S*s. A related issue, which remains unanswered, is whether the higher levels of autonomic activity found for BD patients in earlier studies (Parsons & Chandler, 1969; Holloway & Parsons, 1969) and the impairment of HR habituation in the present and in the Davidoff and McDonald (1964) study reflect functions which are important and relevant to the BD *S*'s distractibility or inability to attend to environmental demands.

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